Electronic Version
Stylesheet Version v1.1.1

Description

[COMMON SECOND LEVEL FRAME EXPOSURE FOR EMBEDDED ATTENUATED PHASE SHIFT MASKS]

BACKGROUND OF INVENTION

[0001] Field of the Invention

[0002] The present invention is directed to the manufacture of masks used in the lithographic production of integrated circuits and, in particular, to the manufacture of embedded attenuated phase shifting masks (EAPSMs).

[0003] Description of Related Art

[0004] As an alternative to chromium on glass (COG) masks used in the lithographic production of integrated circuits, phase shifting masks (PSMs) have been employed in order to increase the resolution of the critical active area patterns projected. Such increased resolution enables smaller line widths to be exposed on the resist and consequently etched into or deposited on the wafer substrate. Some

PSMs have used chromium as an opaque layer in conjunction with phase shifting image segments on the mask substrate, which correspond to areas of critical structures to be exposed with the PSMs.

[0005] Other PSMs for example, embedded attenuated phase shift masks (EAPSMs), utilize opaque layers of chromium to mask non-critical areas outside of the critical structure areas. As used herein, the term critical structures includes lines, contacts and other active regions to be exposed in a resist layer, subsequently developed, etched and/or deposited on the wafer to form an integrated circuit device or portion thereof. These phase shifting image segments typically impart a 180° phase shift of the polarization of the energy beam, e.g., visible or ultraviolet light. In manufacturing an EAPSM, a first exposure is typically made to create the phase shifting and opaque image segments on the substrate corresponding to areas of the critical structures, and a second exposure is made to selectively remove the opaque material but to leave the opaque and the area surrounding the area critical structures.

[0006] Typically, EAPSMs have been produced with costly laser or electron beam writing tools. While a typical COG mask may take 24 hours to fabricate, because of the require-

ment of utilizing two exposures, EAPSMs can take significantly longer to fabricate, up to 42 hours or more. This extended manufacturing time also ties up the use of the laser or electron beam writing tools. Additional costs are incurred in utilizing the laser and electron beam writing tools where the EAPSM is damaged or redesigned , or otherwise reworked, and must therefore be remanufactured. As a result EAPSMs while being extremely effective are also significantly more expensive to manufacture.

SUMMARY OF INVENTION

[0007] Bearing in mind the problems and deficiencies of the prior art, it is therefore an object of the present invention to provide a method of manufacturing embedded attenuated phase shifting masks (EAPSMs) in a less time consuming and less costly manner.

[0008] It is another object of the present invention to provide a method of manufacturing EAPSMs which reduces the time for employing laser or electron beam tools.

[0009] A further object of the invention is to provide a method of manufacturing EAPSMs which simplifies the second level exposure to remove unwanted chrome image segments from the mask.

[0010] It is yet another object of the present invention to provide

an improved method of remanufacturing reworked, damaged and/or redesigned EAPSMs.

[0011] The above and other objects, which will be apparent to those skilled in the art, are provided in the present invention which is directed to a method of making an embedded attenuated phase shift mask (EAPSM) comprising initially providing a phase shift mask substrate having a layer of phase shifting material and a layer of an opaque material, and depositing a first resist layer on the substrate. The first resist layer is exposed and developed, and the substrate is etched, to create first level phase shifting image segments on the substrate corresponding to areas of critical structures to be exposed with the EAPSM. The method then includes depositing a second resist layer on the substrate. There is then provided a single frame exposure mask corresponding to non-critical areas outside the critical structure areas. Using the single frame exposure mask, the second resist layer is then exposed. The method then includes developing the second resist layer and etching the substrate to remove the opaque material from the critical structure areas.

[0012] Preferably, a direct write electron beam or laser energy source is used to expose the first resist layer, and the

second resist layer is exposed by an energy source other than the energy source used to expose the first resist layer. More preferably, the second resist layer is exposed by simultaneous projection exposure.

[0013] The method may further include identifying and storing the single frame exposure mask for future use with the EAPSM. Where the EAPSM needs to be reworked, is damaged or is redesigned, the method may further including using the single frame exposure mask to repair or remanufacture the EAPSM.

[0014] The method may include identifying and storing the single frame exposure mask for future use with other EAPSMs in the same mask set as the EASPM, or with other EAPSMs having the same chip or field size as the EASPM.

[0015] The single frame exposure mask may use a 1:1 reduction ratio to expose the second resist layer, or a reduction ratio other than 1:1.

Brief Description of Drawings

[0016] The features of the invention believed to be novel and the elements characteristic of the invention are set forth with particularity in the appended claims. The figures are for illustration purposes only and are not drawn to scale. The invention itself, however, both as to organization and

method of operation, may best be understood by reference to the detailed description which follows taken in conjunction with the accompanying drawings in which:

[0017] Fig. 1 is a cross-sectional elevational view of the commencement of the process of creating the first level exposure of phase shifting image segments, corresponding to areas of critical structures to be exposed, on an EAPSM.

[0018] Fig. 2 is a cross-sectional elevational view of the completed first level exposure of the EAPSM of Fig. 1.

[0019] Fig. 3 is a top plan view of the single frame exposure mask used in connection with the present invention.

[0020] Fig. 4 is a cross-sectional elevational view of the commencement of the process of creating the second level exposure to remove opaque material from the critical structure areas of the EAPSM of Fig. 1, using the single frame exposure mask of Fig. 3.

[0021] Fig. 5 is a cross-sectional elevational view during the process of creating the second level exposure of the EAPSM of Fig. 1, after the resist layer has been developed and partially removed.

[0022] Fig. 6 is a cross-sectional elevational view of the completed second level exposure of the EAPSM of Fig. 1.

DETAILED DESCRIPTION

[0023] In describing the preferred embodiment of the present invention, reference will be made herein to Figs. 1-6 of the drawings in which like numerals refer to like features of the invention. Features of the invention are not necessarily shown to scale in the drawings.

[0024] Fig. 1 depicts the commencement of the process of fabricating the EAPSM in accordance with the present invention, wherein a mask substrate 20 which is transparent to the energy source to be used in the lithographic production of the integrated circuit device, is overlaid with a layer 22 of a phase shifting material which is then overlaid with a material layer 24 which is opaque to the lithographic energy source. Typically, the transparent substrate 20 is quartz. The phase shifting material may be any conventionally used in the art such as $MoSi_x$, $MoSi_xO_yN_z$, Si_xN_y or CrO_xF_y. In addition to these phase shifting materials, the quartz substrate itself may be made to induce a phase shift by etching the image segments to different levels, i.e., thicknesses, beneath the surface of substrate 20 such that desired phase shift is imparted to the energy beam.

[0025] Opaque layer 24 may be made of any suitable material such as chromium. Deposited over the phase shifting and

opaque layers is a resist layers is a resist layer 26. This resist may be a positive resist, in which a region to be printed is exposed to the energy source, or a negative resist in which the region to be printed is not exposed to the energy source. In the resist layer 26 depicted in Fig. 1, regions 26a, 26b, 26c and 26d are to be developed and removed from resist layer 26 in order to etch the underlying opaque layer 24 and phase shifting material layer 22. These image containing areas 26a, 26b, 26c and 26d are created by a modulated electron beam or laser writing tool 18 which directly writes the image into the resist layer without the use of a mask.

[0026] Following the first level exposure of resist layer 26, the resist layer is developed and areas of 26a-26d are removed. Thereafter, a suitable etchant is utilized to etch corresponding openings in opaque layer 24 and phase shifting material layer 22. After removal of the remaining resist layer 26, the resulting structure is depicted in Fig. 2, wherein phase shifting segments 22a, 22b, and 22c have overlying opaque segments 24a, 24b, 24c, respectively. These image forming segments 232a-22c are in the areas of critical structures to be exposed using the EAPSM. This critical structure area is shown having a width

dimension C. Portions of the opaque layer 24 also remain outside of this critical area.

[0027] In accordance with the present invention, a single frame exposure mask 30 is utilized, as depicted in Fig. 3. The single frame exposure mask 30 is manufactured to have an opening 38 of dimension C, bounded by mask edge 31, corresponding to the dimension of the critical area C to be exposed with the EAPSM. As shown, the mask 30 has a 1:1 reduction ratio, i.e. is the same size as the critical area C on the EAPSM. Mask opening 38 may have other sizes to correspond to other reduction ratios, either greater than or less than the 1:1 reduction illustrated.

[0028] In fabricating the EAPSM mask in accordance with the present invention, a second resist layer 28 is applied over the etched opaque and phase shifting image segments created by the first exposure on EAPSM substrate 20, and mask 30 is secured thereover (Fig. 4). Energy source 34, utilizing visible light, UV or other energy beams 36, simultaneously exposes resist layer portion 28a corresponding to the critical area of the mask. After exposure, the second resist layer 28 is developed and exposed area 28 removed, to arrive at the structure shown in Fig. 5. While resist layer portions 28b and 28c remain over the

areas outside of the critical structure area, and all resist is removed from within these portions. The remaining opaque layer regions 24a, 24b and 25c within the critical area are then etched away, and the remaining second level resist is removed, which results in the structure shown in Fig. 6. In the finished EAPSM mask depicted, the unwanted opaque layer 24 segments have been removed from within the critical area C, leaving only the chromium layer segments 24d, 24e in the non-critical areas outside of the critical area. The remaining phase shifting image segments 22a, 22b and 22c may now be used in connection with transparent substrate 20 to impart the desired phase shifting pattern, using a photolithographic process, in the active area of integrated circuit device wafer substrate.

[0029] Energy source 34 (Fig. 4) is preferably a source other than the electron beam or laser writing energy source utilized to create the first level exposure, so that in the second level exposure level depicted in Figs. 4-6, a less costly optical projection system may be utilized.

[0030] Following the manufacture of the EAPSM depicted in Fig. 6, mask 30 may be marked with an identification and stored in a library of such masks for future use. The identification may be marked with the particular EAPSM mask

in a given mask set, or with identification of the same chip and/or field (critical area) size. In the event that a particular EAPSM mask, or one similar to it, needs to be reworked, or is damaged or redesigned, the single frame exposure mask 30 identified with that particular type of EAPSM may be obtained from the mask library for use in remanufacturing the second level exposure. In view of the use of multiple EAPSM mask layers depending on the design rules, such as where 130mm nodes may use 2-7 EAPSM masks and 90mm nodes may use 8-9 EAPSM masks, the present invention presents a substantial improvement since only one single frame exposure can be used.

[0031] Thus, the present invention provides for the manufacturing of EAPSMs in a less time consuming and less costly manner which simplifies the second level exposure to remove unwanted chrome image segments from the mask by reducing the time for employing laser or electron beam tools.

[0032] While the present invention has been particularly described, in conjunction with a specific preferred embodiment, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art

in light of the foregoing description. It is therefore contemplated that the appended claims will embrace any such alternatives, modifications and variations as falling within the true scope and spirit of the present invention.